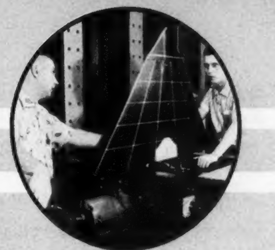
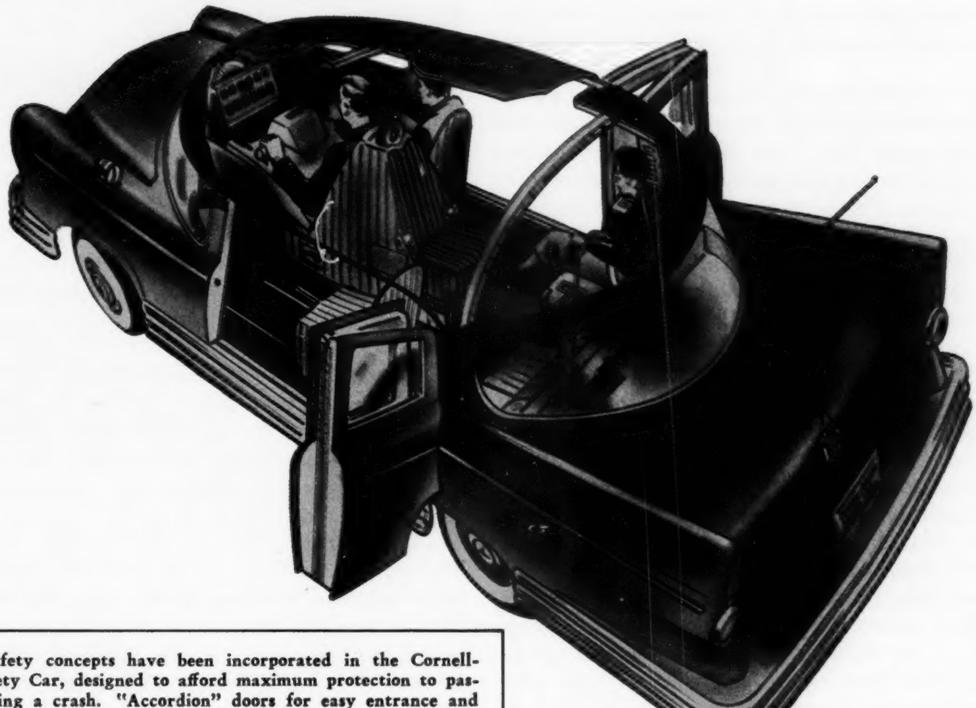
Vol. V, No. 3, Fall 1957

research trends

CORNELL AERONAUTICAL LABORATORY, INC., BUFFALO 21, NEW YORK





Over 60 safety concepts have been incorporated in the Cornell-Liberty Safety Car, designed to afford maximum protection to passengers during a crash. "Accordion" doors for easy entrance and exit, bucket seats for better lateral support to the hips, body-restraining panels and seat belts, are among the safety features illustrated here.

DESIGNED FOR *Living!*

by EDWARD R. DYE

Cornell-Liberty Safety Car Affords Maximum Protection to Passengers

In the past, the amount of injury a person received in a severe automobile accident was considered just plain luck. If he walked away unhurt, he was considered lucky. If he was seriously injured, his luck was bad. Such expressions concerning luck were, of course, admissions of ignorance of the complex kinematics of the human and the structural behavior of the vehicle which take place during the crash period.

The over-all problem, of course, is an involved one containing many variables. Such a problem does not lend itself to a simple straightforward solution. If it can be broken down into a series of smaller problems, however, the answers to these simple problems can then be fitted together in a manner to provide a better understanding of the whole.

Cornell Aeronautical Laboratory has studied the problems involved in preventing accidents and in protecting airplane and automobile passengers during crashes. Since 1947, the Laboratory's Safety Design Research Department has investigated many facets of the overall problem of protecting passengers. Its program* has led to the recent development of an exhibition Safety Car embodying most of the safety concepts developed over the years of research.

Designed to afford maximum protection to passengers in a crash, the Safety Car is one definitive step

*The program has been conducted under the general guidance of the Cornell Committee for Transportation Safety Research, which is drawn from Cornell University in Ithaca, the Cornell Medical College in New York, and CAL in Buffalo.

taken toward reducing the needless waste of human lives and injuries occurring on the nation's highways.

Head Injury Research

The Crash Injury Research Group of the Cornell University Medical College has gathered automobile injury data which clearly demonstrate that the head is the most vulnerable part of the human body. Much of the automotive safety research at Cornell Laboratory has, consequently, been devoted to the reduction of head injuries. Development of the Safety Car has been predicated on the need to protect the head during a crash.

The first studies were made to determine the principles of protecting a head-like object, that is, a hard shell surrounding a semi-fluid. Hen eggs were used in initial tests. Later, plastic head forms were developed for more realistic studies. These plastic forms were catapulted against various objects to determine the type and character of blows to the head that can occur in a crashing vehicle. Subsequently, the kinematics of the human body were simulated with man-like dummies developed by the Laboratory. These dummies—nicknamed "Thin Man," "Thick Man," and "Half Pint"— were used to determine the position of the body, the path of its flight, and how much the mass of the body contributes to the head impact. For example, a swan-dive movement, typified by a child's flight from the back seat during a head-on crash, was discovered to be ten times more dangerous than the horizontal movement of a child seated in the front seat of the car.

Various objects ranging from knobs to flat surfaces were studied to determine ways to reduce their head-injury potentials. A foam plastic padding with energy-absorbing characteristics, for example, was one result of this particular investigation. The threat of the steering wheel and post was studied, seat belts and shoulder harnesses were tested, car doors and locks were studied in an effort to prevent them from flying open in crashes. Much of this early work — determining how passengers actually move in a crash, and the probability of hitting an object inside the car — was carried out under sponsorship of the Liberty Mutual Insurance Company.

The Cornell-Liberty Safety Car, an exhibition automobile embodying most of the safety concepts developed by Cornell Aeronautical Laboratory over the years of research.

The Safety Car Concept

In 1955 Liberty Mutual and CAL decided that the safety research knowledge acquired to date should be applied to designing a car which would afford occupants maximum crash impact protection. The purpose of this program was to illustrate that a safety car could be engineered, and to make the safety research information available so as to create a public awareness of its features and feasibility. Six basic principles of crash protection were followed in designing this car. The first four are similar to those used daily in packaging any delicate object for shipment: use a strong shipping case, fasten lid securely, pack tightly, and remove hard objects from padding.

First, the car body was made strong enough to prevent most exterior blows from distorting the body against the passengers. Second, doors were secured in such a manner that crash forces could not open them. Thus passengers could not be thrown out and the structural strength of the side of the car body could be maintained. Third, passengers were secured within the car to prevent them from striking objects inside the car during a crash. Fourth, such dangerous objects as knobs, mirrors, and sharp edges were removed.

In addition to the "safe packaging" concept, two other principles were employed in designing the car. The driver's working environment was improved to lessen the chances of an accident by increasing visibility, simplifying controls and instruments, and lowering the carbon monoxide of his breathing atmosphere. Also, dangerous objects were eliminated from the exterior of the car to increase the safety for pedestrians.

Description of the Cornell-Liberty Safety Car

The exterior of the car does not differ greatly in appearance from the average four-door sedan or station wagon. The grille, hood, headlights and bumpers have been redesigned and the radiator ornament has been eliminated to minimize danger to the pedestrian.

In the wrap-around bumper system, plastic foam

THE COVER

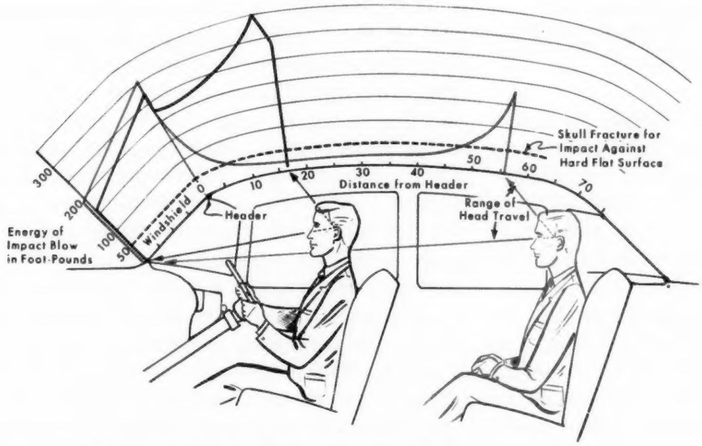
This scaled flutter model of the Navaho wing-aileron configuration is being vibrated in one of its natural modes of vibration. Because of the violent and possibly destructive nature of flutter, these zero airspeed tests are conducted prior to the flutter tests in the CAL eight-foot Transonic Wind Tunnel. The purpose of the vibration test is to obtain experimentally the characteristics of the natural modes of vibration for comparison with calculated results and with the vibration characteristics of the full-scale surface.

material between the front and rear bumpers and the back-up plates absorbs some of the shock energy. In addition, the bumpers are smoothly shaped so that they convert an increased proportion of blows from direct to glancing ones. The side bumpers are connected firmly to the frame which has been extended and reinforced to provide this support.

The car has "accordion" doors, fashioned like telephone booths or bus doors for easy entrance and exit. They are securely closed by three bolt bars which keep the doors closed in a collision, thus maintaining full structural support of the car body. Two roll-over bars, one over the front seat riders and one over the rear, have been incorporated into the top of the car body as added support.

Studies were made of seating the six passengers so that they would be safeguarded both as individuals and as a composite group. Bucket seats were decided upon to give better lateral support to the hips during a crash. Because the driver has the greatest exposure to an accident, he has been placed in the safest possible position — the center front seat — where he has more car body structure between him and the crash contact points.

The other two front seats are placed on either side of the driver, slightly to the rear and slightly lower, so that they do not interfere with the vision or arm movements of the driver. Two forward facing rear seats are placed inside the rear wheel wells. They are not directly behind the front seats but are staggered so that the rear passengers, if thrown directly forward, will not strike the front passengers. There is also a rearward facing seat behind the driver.



Head impact against the roof for unrestrained passengers in a 20 mph front-end collision against a solid object.

Seat Belts and Restraining Panels Added

All passengers are held securely in their seats to prevent them from becoming flying missiles during a crash. The driver is restrained in his seat by a curved control panel that rocks down into position and locks there. The front seat riders are similarly restrained by body-restraining panels that also serve as tables or armrests.

The two forward-facing rear passengers are held in their bucket seats by seat belts of unusual design. These belts automatically reel up when released, with only six inches of belt left exposed. To use the belt, the passenger presses the belt release button at the end of the armrest, unreels the two sections of the belt and fastens the light metal-tip ends together. The fastened belt then settles comfortably into the passenger's lap and remains locked there until the release button is again pressed. Although the rearward facing passenger has the benefit of full spine and head support in a forward crash, he also has been provided with a seat belt. Seat belts were chosen for restraining devices rather than shoulder harnesses because it was felt that the public would more readily accept and use them.

Space clearance between front and rear seats prevents the head of any rear passenger from striking a seat during a crash. A kinematic study of properly-restrained passengers revealed that no head could hit an injury-producing part of the car.

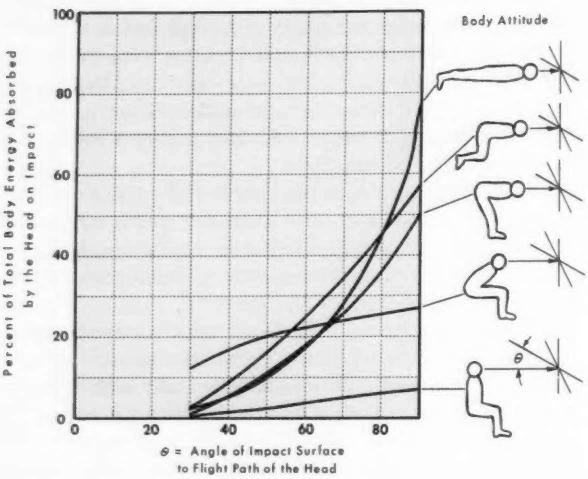
Provision against "whip-lash" injury, which occurs most frequently in the heavy traffic of express highways or city streets during periods of poor visibility, was also made. This type of injury damages the neck and spine when a rear collision causes the head to snap back. As protection, the driver is provided with a pullup headrest that can be quickly positioned. The other riders are protected by nylon harnesses to support the head.

Knobs, projections, sharp edges, and hard surfaces are absent to a great extent from the interior of the car. The driver is still further protected by the elimination of all objects in front of his legs. Besides eliminating dangerous objects, some concealed sharp corners such as the header over the windshield, a common danger point, have been removed and the ceiling has been shaped to produce only glancing blows to the head.

The back shelf in conventional sedans frequently collects packages that become dangerous missiles when the car suddenly stops. This hazard has been eliminated in the Safety Car by lowering the back shelf considerably below the level of the back of the rear seats. As further protection for passengers against flying objects from the rear there is a strong metal partition or bulkhead between the trunk and passenger compartments of the car. This partition prevents tools, baggage, and other heavy objects normally carried in the trunk from being hurled into the seating area.

Guidance Device Used for Steering Wheel

The ordinary steering wheel and steering post, which cause many serious injuries in automobile collisions, have been omitted. A guidance device which has



CAL studies demonstrate the influence of barricade angle and body attitude on head impact. The head of an erect passenger striking a slanting surface receives only a small percentage of the body energy.

a much lower injury potential is used instead. A control panel has been devised which the driver pulls back into his lap, where it latches into position. This curved control panel rests lightly against the lap and provides a safety restraint similar to that of a safety belt. Push button controls (flush with the panel) for driving the car are on this panel, all within fingertip reach.

In the new concept of steering developed for the Safety Car, steering power is supplied by hydraulic pressure. The driver could guide the car with the control handles as though he were steering a sled, using one hand or both. The arms and the hands are in a comfortable position, and no great motion is required for a full turn of the wheels. At normal driving speeds (over 25 mph), where only small wheel deflecting angles are required, the sensitivity would be about that of a normal steering gear. However the ratio decreases for the larger wheel deflective angles. The steering can be described as a variable ratio, variable force, and variable rate, full-hydraulic system. To date, this novel guidance system has not been dynamically tested, but it is believed to have considerable promise and deserves careful consideration.

A soft pad in front of the driver's chest gives additional protection from chest injuries. The parking brake and the ignition switch are mounted on either side of the instrument panel. The conventional brake and the accelerator are on the floor. All other controls, such as door handles, radio controls, heating and ventilating adjustments are located on the side of the driver's cockpit.

The instruments are placed well out of the range of the driver's head and are located just under the line of sight over the hood where they can easily be seen. The speedometer, the only navigational instrument of an automobile, is prominently displayed. All other instruments are operational instruments and need attention only if malfunctioning occurs. If malfunction does occur, a light-panel, placed directly under the driver's line of vision, alerts him to the emergency. Because of this monitoring system, the driver's attention need not be unnecessarily diverted from the road.

Special Ventilating System Added

Since carbon monoxide is a heavy gas which, breathed in even small quantities, reduces alertness, ventilating air should be collected from the highest possible level. The ventilating system of the Cornell-Liberty Safety Car efficiently and safely attacks this lethal hazard. Window ventilators are not used because of their head-injury potential. Instead, the air enters the car at the top of the windshield under the roof projection and is fed into the forward roll-over structure which acts as a plenum chamber to distribute fresh air into the car at the nose level and/or foot level of the front passengers. In winter, the air is conducted through an underseat heater. Air leaves the car through louvres above the rear seat armrests. The rear roll-over structure becomes a duct to discharge the air over the top of the rear glass. A slight positive pressure is thereby maintained to prevent infiltration of carbon monoxide gas and dust.

The windshield allows almost 180° clear vision, and, being circular in a horizontal plane, gives no annoying distortion patterns. Furthermore, since it has been designed as the frustum of a cone, the windshield will be well out of the range of the head of any properly restrained front passenger. Almost all of the windshield and back glass can be wiped clean during a storm.

All front seats slide backward to allow easy entrance and exit. The seating arrangement provides convenient and safe places for short-haul storage of handbags and packages on the floor behind the front seats just inside the doors. Because these packages are stored low behind the structurally strong seats, no crash hazard is expected. The rear seat arrangement provides a convenient, safe, and comfortable conversational grouping.

The first principle of safety is to drive carefully, with the car under as nearly perfect control as driving conditions will permit. Despite all precautions, however, accidents will happen.

The Cornell-Liberty Safety Car is an assembly of research design ideas to illustrate means of giving the passengers the best possible protection during the crash period. These ideas, when improved upon and incorporated into production automobiles, may very well be the means of substantially reducing the ever-rising death and injury toll on our American highways.

The following have contributed financial support or components to the Cornell-Liberty Safety Car: Pittsburgh Plate Glass Co.; King Seeley Corp.; A.C. Spark Plug Division of G.M.; Owens-Corning Fiberglass Corp.; U.S. Rubber Co.; Standard Products Co.; Bendix Aviation Corp.; Irving Air Chute Co.; Colorado State Medical Society; Rigidized Metals Corp.; Houdaille Industries, Inc.

"MIXED" *Motions!*

by JOHN M. SCHULER

A New Problem in Airplane Stability and Control

To give the fighter pilot the maneuverable airplane he needs, the aircraft designer has long made higher and higher roll rates his watchword. He has at long last reached a limit — his airplanes roll too fast!

There was a time when airplanes needed large wings to support them in flight. Such wings provided the airplane with substantial rolling resistance. If the airplane was to roll rapidly, then, powerful ailerons were mandatory. With the advent of supersonic flight, the wing shrank appreciably in comparison to the fuselage. Such stubby wings provide relatively low rolling resistance, and also substantially reduce the moment of inertia in roll as compared to that in pitch and yaw — a trend further accentuated by the long thin fuselage characteristic of modern fighters. So it is not surprising that supersonic fighters are capable of high roll rates and high roll accelerations.

Two sources of difficulty now enter the picture: the "inertia coupling" or gyroscopic phenomena produced by rolling a long thin body (the airplane) very rapidly, and the "aerodynamic coupling" associated with stubby wings. Both phenomena are important because of their "coupling" tendency, that is, they couple the motions about the three airplane axes of rotation: roll, pitch, and yaw. Thus, rolling motion will produce pitching and yawing motions, and either of these latter motions will produce the other two.

The coupling tendencies are generally nonlinear in nature, so their inclusion in theoretical treatment tremendously magnifies the difficulty of dynamic analysis. The airplane dynamicist has been aware of this coupling, but until recently he has usually neglected it. However, in supersonic airplanes, the inertia coupling and aerodynamic coupling prove to be much greater than for earlier airplanes. Recent flight experience has shown conclusively that these coupling effects must receive careful consideration.

For example, Figure 1 shows time histories of normal and transverse accelerations for what was meant to be a normal aileron roll. The ensuing motion, described by the pilot as a "hairy" maneuver, severely overstressed the airplane. In this case, the airplane has been designed without adequate provision for the coupling effects in rolling maneuvers.

Though severe coupling effects leading to wild gyrations in level flight rolls are a rather recent phenomenon associated with high-speed research and fighter aircraft, a look back shows that coupled motions have always been a problem, notably in stalls, spins, and rolling pull-outs. Studies of stalls and spins have naturally been concerned principally with recovery techniques. But studies of the rolling pull-out maneuver (a roll initiated from a pull-up or a turn) have been primarily quantitative and directed toward prediction of vertical tail loads. Theory originally developed to describe the motions in a rolling pull-out is now found applicable to the general problem of coupled motions and, in particular, to the study of these motions when they become so large as to be classified as uncontrollable.

Developing a Theory

The study of large uncontrolled motions began in World War II when investigations by the NACA showed that certain vertical tail failures were caused by maneuvers involving a simultaneous roll and pull-up. Large sideslip angles encountered in these maneuvers were the source of the trouble. Simplified equations developed for these early cases of tail failures in rolling pull-outs were later found to be inadequate. Further experiments and efforts by manufacturers to design for this phenomenon led to considerable confusion; a number of different methods and equations were developed and proposed for use in design.

Because of past research experience in the field of dynamic stability and control, CAL was asked by the Wright Air Development Center in 1949 to conduct a comprehensive study of the rolling pull-out maneuver. The purpose was to find a good method for estimating tail loads. The program was simple: write the most complete equations possible and simplify them on the basis of computed solutions, flight test an airplane, and then compare theory and flight test data. A set of equations resulted which could predict satisfactorily the motions of an airplane in a rolling pull-out.

Initial theoretical studies, performed on a digital computer, showed that the rolling pull-out was essentially a constant-speed maneuver and that changes in speed could be neglected. The studies also showed that both inertia coupling and aerodynamic coupling had to be included. Results are summarized in Figure 2 by showing the sideslip angles computed for a rolling pull-out. The equations of motion with speed change neglected give excellent results. Five degrees of freedom are included: normal and transverse velocities, and rotation about the roll, pitch, and yaw axes.

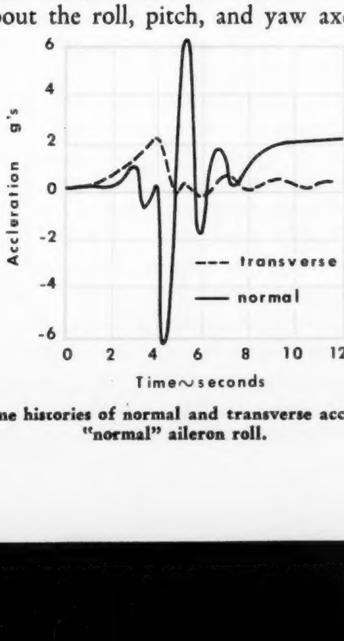


FIG. 1 **Time histories of normal and transverse accelerations in a "normal" aileron roll.**

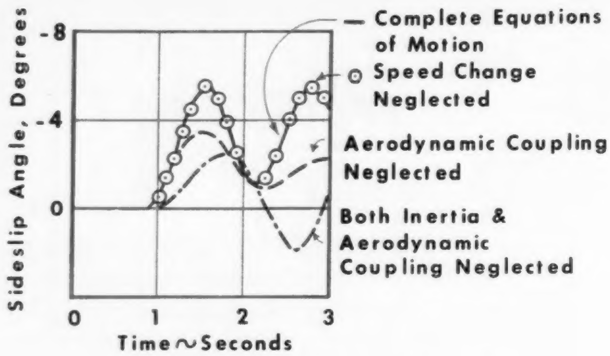


FIG. 2 — Computed sideslip angle in a rolling pull-out.

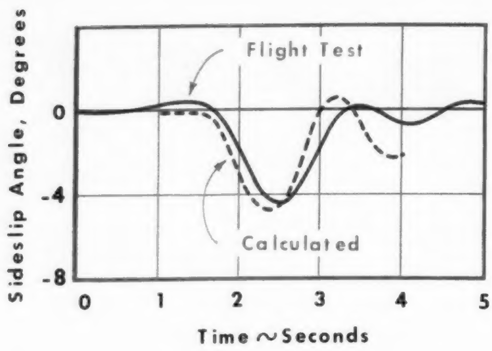


FIG. 3 — Comparison of flight test and calculated sideslip angles in a rolling pull-out.

A fully instrumented F-80A airplane was used to gather a large body of flight test data. An analogue computer, using the five-degree-of-freedom equations, calculated comparable responses. The agreement shown in Figure 3, actually quite good, typifies that generally obtained.

Applying the Theory

The trend in modern airplane design toward small short wings mounted on long slender fuselages (i.e., high wing loadings, low aspect ratios, and low rolling moments of inertia) has led to more extreme motions in rolling pull-outs. In 1953, Cornell Aeronautical Laboratory undertook to study the problem as applied to modern fighters. Calculation of tail loads remained the primary objective. However, once the motions are defined the tail loads can be predicted with some confidence. For this reason, better understanding of the dynamics was emphasized. Results of this investigation show that inertia and aerodynamic coupling effects can dominate the aircraft's response and can lead to severe and uncontrollable gyrations in rolling maneuvers. The response shown in Figure 1 typifies such a gyration. Comparatively simple intuitive concepts lead to an understanding of the mechanics of these gyrations. One part of the problem deals with inertia coupling, the other part with aerodynamic coupling.

The airplane shown in Figure 4 is rolling about its flight path at an angle of attack. The mass of the airplane is considered to be concentrated into two equivalent masses representing those portions of the airplane fore and aft of the center of gravity. Centrifugal forces will try to force the airplane to a position normal to the flight path. Thus, there is an effective pitching moment on the airplane proportional to the product of the rolling velocity and the angle of attack. The inherent aerodynamic stability of the aircraft will resist the pitching motion. But in general there is some critical roll rate above which the inertia forces overcome the aerodynamic stability. If the critical roll rate is exceeded, the airplane will perform a "whirling divergence" (align itself normal to the flight path).

Now let us roll the airplane about its principal axis (the axis passing through the effective masses shown in Figure 4) instead of about the flight path. The inertia coupling forces (shown in Figure 4 as centrifugal forces) will be reduced to zero. After rolling this airplane 90° about its principal axis (Figure 5) the airplane will have swapped its angle of attack for angle of sideslip. The inherent aerodynamic stability will now cause large pitching and yawing moments in an effort to restore the airplane to its original condition, i.e., zero sideslip and positive angle of attack. These restoring moments will make the airplane wobble and again bring the inertia coupling forces back into action. The net result again will be to initiate a whirling divergence if the roll rate is large enough.

At this point one of the most influential aerodynamic coupling effects enters the picture: the rolling moment due to sideslip. For wings with low aspect ratio or high sweep, this rolling moment is large and roughly proportional to the negative product of angle of attack and sideslip. For an airplane rolling about its principal axis, as in Figure 5, the dihedral effect initially inhibits the roll rate; but from 45° to 225° the roll rate increases rapidly. Studies show that if an airplane actually rolls in this manner (i.e., rolls about its principal axis with this axis initially at a positive angle of attack), then once the angle of attack becomes negative, it is virtually certain that an uncontrollable gyration will develop.

Although the foregoing concepts of the mechanics of rolling are somewhat simplified, they do include the important aspects of coupled motion. In an actual maneuver — an aileron roll, a rolling pull-out, or a turn entry — the airplane will start to roll about some skewed axis which is near to, but not coincident with, either the flight path or the principal axis. The position of this roll axis will depend on the airplane configuration, flight condition, and specific control motions used in the maneuver. Undesirable tendencies — rotation

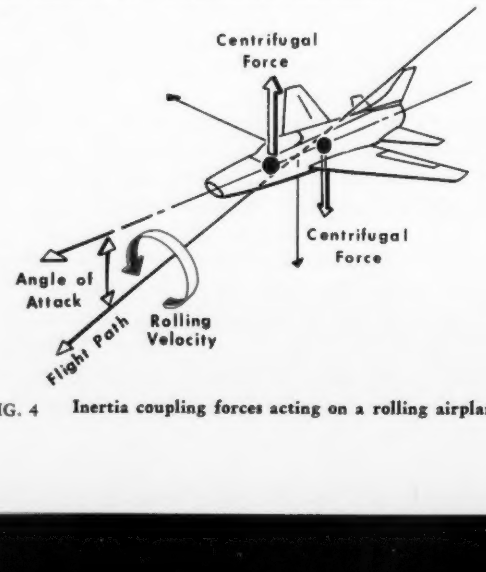


FIG. 4 Inertia coupling forces acting on a rolling airplane.

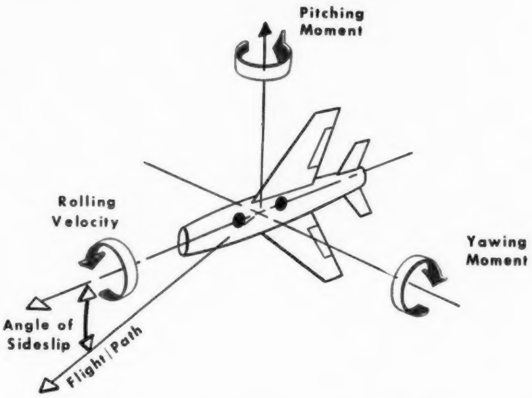


FIG. 5 — **Aerodynamic moments acting on a rolling airplane.**

normal to the flight path and the interchange of angle of attack and sideslip — are resisted by the aerodynamic stability in both pitch and yaw. If the airplane has a high level of stability, then high roll rates may be used in maneuvering without causing uncontrollable gyrations. Thus, the areas where difficulty can be expected are those regions in the flight spectrum where stability is lowest. These areas are recognized as: (1) low-speed flight near stall; (2) high-altitude flight where the air is rarified and the aerodynamic forces are relatively small; and (3) high-speed supersonic flight where stability, particularly in yaw, tends to deteriorate.

Each of these problem areas has its own peculiar characteristics. In low-speed flight the problem is principally one of control in spins, incipient spins, and post-stall gyrations. At high altitudes the problem is one of maintaining maneuverability without loss of control. At high speeds, the airplane's motions during maneuvers must be kept sufficiently small so that the safe structural loads are not exceeded and the pilot is not subjected to excessive accelerations. Though each of these problems is different in detail, they are all dominated by the same basic phenomena — the inertia and aerodynamic coupling associated with large disturbance motions. The problem is one of dynamics and relies on the theory of nonlinear differential equations — at best, a tough combination to treat analytically.

What of the Future?

What are the future design implications of these problems? Assuredly, the aircraft configuration trends which have led to this problem will continue in the same direction. Wings will get smaller, fuselages will grow longer, and airplanes will fly higher and faster. Emphasis will shift — it has to some extent already — on the subject of roll rate. Instead of trying for higher roll rates, the airplane designer may now try to limit the available maximum roll rates to an acceptable minimum, perhaps eventually eliminating roll as a means of maneuvering. On the other hand, the possibility of stabilizing the airplane by automatic control may restore respectability to high roll rates.

Even if the roll problem is solved, the low-speed problem associated with spins remains. Modern airplanes have been known to perform large uncontrolled motions at low speeds in essentially a level flight condition. The motion is precipitated by the loss of stability near the stall and develops into an extreme maneuver similar to an oscillatory spin. All of these low-speed problems are related, involving inertia coupling, loss of stability, and aerodynamic coupling of roll, pitch, and yaw. CAL is now investigating these low-speed problems and, like earlier research in this field, the results will give the designer another tool with which he can build better and safer airplanes.

REPORTS

"Analytical Study of Airplane Dynamics and Tail Loads in Rolling Pull-out Maneuvers," by Schuler, John M., WADC TR 56-403 (CAL Report No. 916-F-1), Sept. 1956.

"A Theoretical and Experimental Study of Airplane Dynamics in Large-Disturbance Maneuvers," by Rhoads, D. W., Schuler, John M., Journal of Aeronautical Sciences, July 1957.

ABOUT THE AUTHORS

EDWARD R. DYE, Head of CAL's Safety Design Research Department, was an original member of the Cornell Committee for Air Safety Research. Safety studies under that group led to his later work in automotive safety research. The Cornell-Liberty Safety Car, recently unveiled, stands as the culmination of his work to date in the field of safety research.

Mr. Dye joined Curtiss-Wright in 1942 as Assistant Head of the Physics Department. Before his present appointment, he served as Head of the Development and Industrial Divisions at CAL. His broad background also includes work as a structural engineer, as a professor of civil engineering, and as head of a static test group of Douglas Aircraft. In 1950 he received a Buffalo Evening News citation for outstanding public service.

He has both a B.S. in Civil Engineering and a Civil Engineering degree from Purdue University. He is a member of eight professional and honorary societies.

JOHN M. SCHULER, Project Engineer on CAL's rolling pull-out program, has been engaged in research on airplane dynamics ever since his graduation from Princeton in 1951. That year, while doing graduate work, he worked for Chase Aircraft Company as a part-time member of the Aerodynamics Department. From 1952 to 1954 he was employed by Douglas Aircraft Company as an aerodynamicist in the stability and control group, where he became interested in the rolling pull-out program. During 1953 and 1954 he was employed by the Del Mar Engineering Laboratories, on a consulting basis, to study the dynamic stability and control problems of towed gliders and target drones.

Mr. Schuler joined CAL's Flight Research Department in 1954. He is now working on a new program, initiated to study the large uncontrolled motions of aircraft.

He has a B.S.E. degree from Princeton and is currently engaged on a thesis for his M.S. degree. He is a member of the I.A.S.

RECENT C. A. L. PUBLICATIONS

The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited; and those marked with an * may be distributed only within the United States. Please direct your request to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"ENGINEERING EVALUATION OF THE BISHOP VARIABLE-RATIO STEERING GEAR," Reece, J. W.; CAL Report YM-1080-F-1; Feb. 23, 1956; 35 pages.

This report comprises an engineering evaluation of a type of automotive steering gear proposed by A. E. Bishop, characterized by having a ratio which decreases as wheel is turned from the in-line position.

"KINEMATICS OF THE HUMAN BODY UNDER CRASH CONDITIONS," Dye, E. R.; reprinted from the Clinical Orthopaedis, No. 8; 1956, 5 pages.

The considerations of the complex and violent motions described by the various parts of the human body and of the forces associated with their deceleration are the subject of this discussion.

"VECTOR EQUATIONS OF MOTION FOR A RIGID BODY," Schuler, J. M.; CAL Report FRM-251; June 20, 1956; 11 pages.

The equations of motion for the automobile are written, starting from basic principles. The vector equations of motion for a rigid body are presented.

"DEVELOPMENT OF STALL WARNING FOR THE T-34B AIRPLANE," Bull, G.; CAL Report IH-1019-F-1 (NOas 55-752-c); November 1, 1956; 115 pages.*

Successful modifications to produce satisfactory stall warning are described.

"EFFECT OF PRANDTL NUMBER ON THE HEAT TRANSFER PROPERTIES OF A TURBULENT BOUNDARY LAYER WHEN THE TEMPERATURE DISTRIBUTION ALONG THE WALL IS ARBITRARILY ASSIGNED," Ferrari, C.; Reprinted from Zeitschrift Fur angewandte Mathematik und Mechanik; Vol. 36, No. 3-4; March/April, 1956; 20 pages.

The influence of Prandtl's number on the recovery factor is determined; then the formulas giving Nusselt's number are derived. The experimental results agree with the calculated ones.

"THE NUMERICAL INTEGRATION OF TWO-POINT BOUNDARY VALUE PROBLEMS," Goodman, T. R. and Lance, G. N.; Reprinted from Mathematical Tables and Other Aids to Computation; Vol. 10, No. 54; April 1956; 6 pages.

"THE TIP CORRECTION FOR WIND TUNNEL TESTS FOR PROPELLERS," Goodman, T. R.; Reprinted from Journal of Aeronautical Sciences; Vol. 23, No. 12; December 1956; 4 pages.

Two corrections are obtained quantitatively in an approximate manner for incompressible flow.

"THE INFLUENCE OF COMPRESSIBILITY ON THE STEADY STATE WALL INTERFERENCE ON PROPELLERS OPERATING AT HIGH SUBSONIC MACH NUMBERS IN A WIND TUNNEL," Curtis, J. T.; CAL Report No. AB-625-W-23 (AF33(600)-23740); November 1956; 29 pages.*

The effect of tunnel walls upon the performance of propellers tested at high subsonic speeds is deduced by application of the axial momentum theory to the steady flow of a compressible fluid through an actuator disk.

"THE APPLICATION OF THE SHOCK TUBE TO THE STUDY OF HIGH TEMPERATURE PHENOMENA IN GASES," Hertzberg, A.; Reprinted from Applied Mechanics Review, Vol. 9, No. 12; December 1956; 16 pages.

The relationship of the shock tube to the study of hypersonic flight, high-temperature chemical kinetics, and high-temperature gas physics.

"NITRIC OXIDE FORMATION IN HYPERSONIC FLOW," Logan, J. G., Jr.; Reprinted from Journal of the Aeronautical Sciences, December 1956; 3 pages.

A description of investigations of the NO reaction.

"RADAR VIDEO INTEGRATOR STUDY," Hendrick, R. W.; CAL Report No. 78; January 1957; 51 pages.

Experimental, computational and theoretical results all are in essential agreement and predict that automatic radar equipment utilizing video integration should operate satisfactorily at ranges 1.5 to 2 times that possible using the raw video. Automatic operation should be comparable to alert operator operation.

"ON THE INSTABILITY OF SMALL GAS BUBBLES MOVING UNIFORMLY IN VARIOUS LIQUIDS," Hartunian, R. A. and Sears, W. R.; June 1957; 20 pages.

The experiments consist of the measurement of the size and terminal velocity of bubbles at the threshold of instability in various liquids, together with the physical properties of the liquids. The results of the experiments indicate the existence of a universal stability curve.

"HIGH TEMPERATURE RUPTURE-STRENGTH PROPERTIES OF CHROMIUM-NICKEL STAINLESS STEELS CONTAINING TITANIUM AND BORON," Salvaggi, J. and Yerkovich, L. A.; Reprinted from the American Society for Metals, Trans., Vol. 49, Preprint No. 33; November 1956; 19 pages.

Interest has existed among high-temperature alloy producers and jet engine manufacturers in utilizing leaner alloys for aircraft construction than are currently specified. The modified steels discussed here offer possibilities in this respect.

"USE OF AN ADAPTIVE SERVO TO OBTAIN OPTIMUM AIRPLANE RESPONSES," Campbell, G.; CAL Report 84; February 1957; 63 pages.

The purpose of this investigation is to demonstrate the feasibility of obtaining a desirable transfer function by means of a linear adaptive servo. The unique applicability to airplane handling qualities is shown.